

# Why Harsh Environments

- Dense urban terrain represents the single most hazardous setting for engagement
- Casualty rate extremely high
- Increasing shift of world population to cities  
85% of world population by 2024
- GPS often ineffective
- Need to protect our forces, remove personnel from areas of high threat, deploy sensors & robots
- Other harsh settings: on ships, inside cargo containers, close to the ground...

## UWB Claims

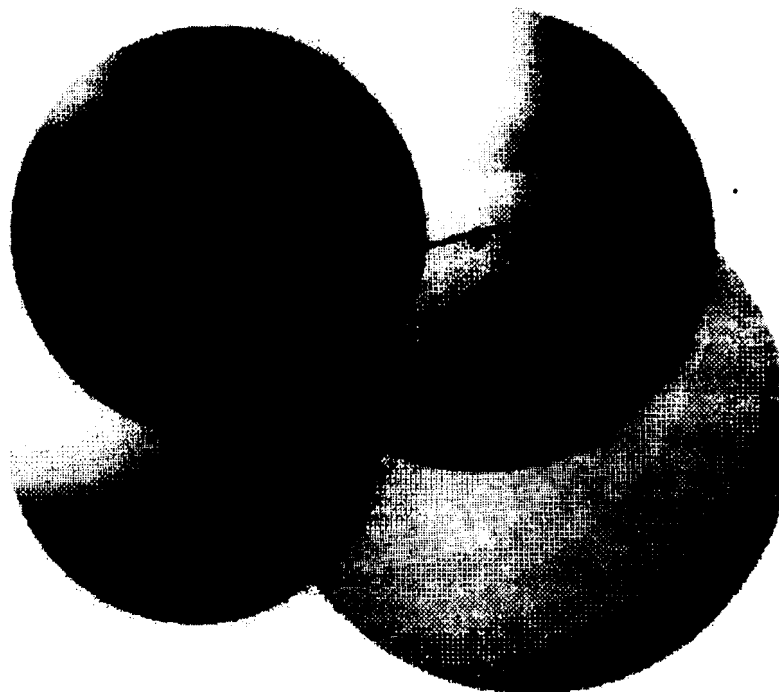
- No fading from destructive interference  
(coherent effects are less)
- Potential for single chip, all digital  
(cost savings)
- Lower power dissipation  
(few analog components)
- Built-in LPI/LPD/LPJ
- No need to get spectral allocation  
(uwb signal is buried in the noise)
- Penetration capability - walls, ground  
(enabled by low frequency component)
- High precision ranging  
(enabled by high frequency component)

- Focus on the real advantages of UWB
- Design and implement next-generation UWB hardware and software for ad-hoc networking in extreme environments.
- Develop uwb network-based geolocalization system
- Demonstrate key DOD applications in appropriately harsh, environments

# Technical Areas

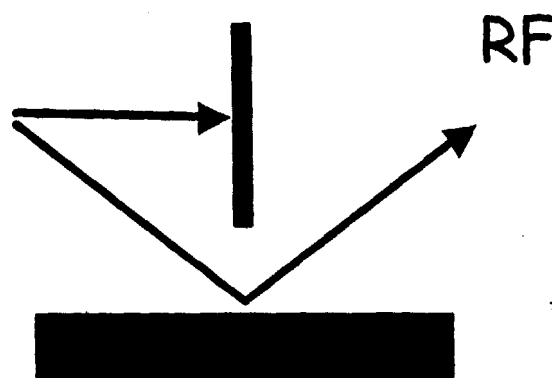
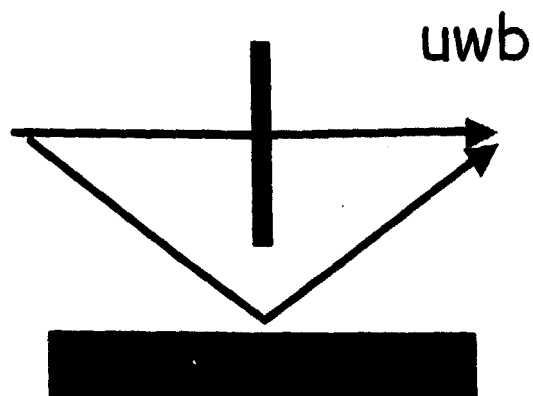
## Precision Geo-Localization

- 3-D multi-lateration
- scalable and power-efficient geolocation techniques
- in-depth tradeoff analysis  
(accuracy vs.  
power, number of nodes ..)
- mobility support



# UWB Geolocalization Advantage

- GHz bandwidth gives sub-centimeter resolution
- inherent part of UWB networking node (no need for separate hw)
- smaller sensitivity to multipath delay ??



Bandwidth at lower frequencies gives penetrating ability  
Direct path signal may be weaker,  
but if detected, is used as first-arrival signal



# **Ultrawideband (Impulse Radio) Communications Technical Challenges**

**NETEX Industry Day**

**10 September 01**

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# Potential Advantages of UWB



- **Ultrawideband Operation (> 1 GHz)**
  - Better multipath fading performance (like any wideband signal would)
  - Large processing gain (> 40 dB) improves Anti-Jam (AJ) properties
  - Covert operation (Low Probability of Intercept/Detection (LPI/D))
  - Position location on the order of a few centimeters
- **Greatly Reduced Power Consumption**
  - Single chip (CMOS) implementation without mixed signal processing
  - Low duty cycle operation
  - Higher energy efficiency due to pulsed battery operation
- **More Efficient Use of the Spectrum**
  - More users per unit of bandwidth
  - Unregulated (FCC Part 15) operation
  - Reduced near-far interference resulting from low duty cycle operation
  - Full-duplex operation in the same frequency band

**The Potential of UWB Impulse Radio Has Not Been Realized**



# Summary/Conclusion

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- **Ultrawideband - What's Old Is New Again!**
  - Wireless could have gone straight to UWB if DSP had been available ☺
- **A Cornucopia of Commercial and Military Applications**
  - Communications, radar, geolocation, automation, measurement, etc.
- **UWB Has The Potential for Revolutionary Change**
  - Regulatory changes (FCC Part 15?) are needed
- **UWB Research Has Only Just Begun**
  - Propagation, antennas, circuits, devices, waveforms, signal processing, radio architectures, MAC/network protocols, etc.





# **Ultra Wide Band Applications and Requirements**

**DARPA NETEX Industry Day  
McLean, VA**

**10 Sept 2001**

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# UWB Applications: Logistics

DARPA

## Desert Storm

- **First MRC with ISO Containers**
  - 40,000 Containers, Opened 25,000
    - » Paper Manifests Were Inaccurate and Easily Lost
  - ISO Containers Hid the Stuff
    - » Previous MRCs Used Break Bulk
  - Misplaced & Lost Stuff = \$3 Billion
    - » GAO Report B-246015, Dec 1991
- **The BIG Questions**
  - What Do I Have?
  - Where Is My Stuff?
  - What Is In the Box?
  - What Is Its Condition/History?



# UWB Applications: Logistics

DIRDA

## Naval Total Asset Visibility (NTAV)

- **Tackle the Unsolved Hard Problems**
  - Precision Asset Location (PAL)
    - » Where's my Stuff?
    - » Ship Stow Plans
      - 40% Stow Error, Re-Inventory Required
  - Autonomous Manifesting (AM)
    - » What's in the Box?
    - » The "Holy Grail of Logistics"
  - Infrastructure Reduction (IR)
    - » Cost Reduction (\$K's/Reader)
    - » Ship Pre-Installation and Cabling
- **Transportation is a \$1T Industry**
  - DoD is Largest Purchaser of Transportation
  - US CINC Transportation (TRANSCOM)



# UWB Applications: Weapons

DARPA

## Carrier Weapons Management

- **NAVAIR / NAWC Lakehurst**
- **Problem**
  - Aircraft Leave With Partial Loads
    - » Desert Storm: Several Carriers Continuously Launched Aircraft with 2 or Less Weapons
  - Locate Weapon Components for Assembly
    - » Up to 9 hrs for Assembly: 8 Decks, 32 Mags
  - Locate Weapons in Hanger & Flight Decks
    - » Staging Areas, Main Deck, Bomb Farm
- **Hot RF Spots Throughout Carrier**
  - High Powered Radars: EMI / EMC / HERO
- **Proposed Solution**
  - UWB Precision Location of Weapon Sleds: 1 ft
- **Makes Aircraft Carriers More Lethal**



# UWB Applications: Geolocation

DARPA

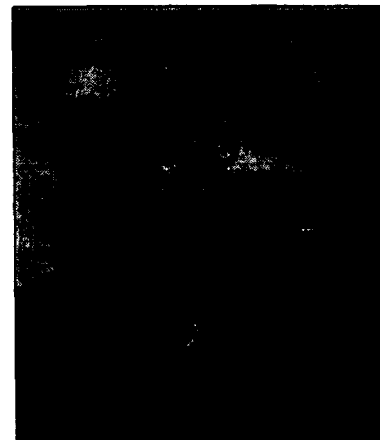
## UAV Landing System

- **UAV Common Automatic Recovery System (UCARS)**

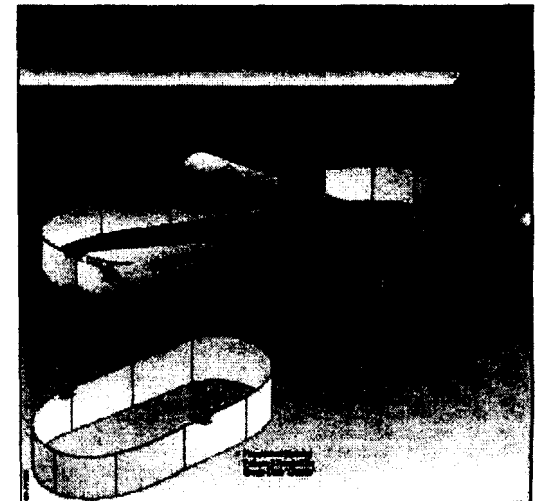
- Pioneer UAV
- Microwave: 3 ft Accuracy
- 6 ft Landing Grid
  - » Pitch / Roll / Stability
  - » Ship Under Way

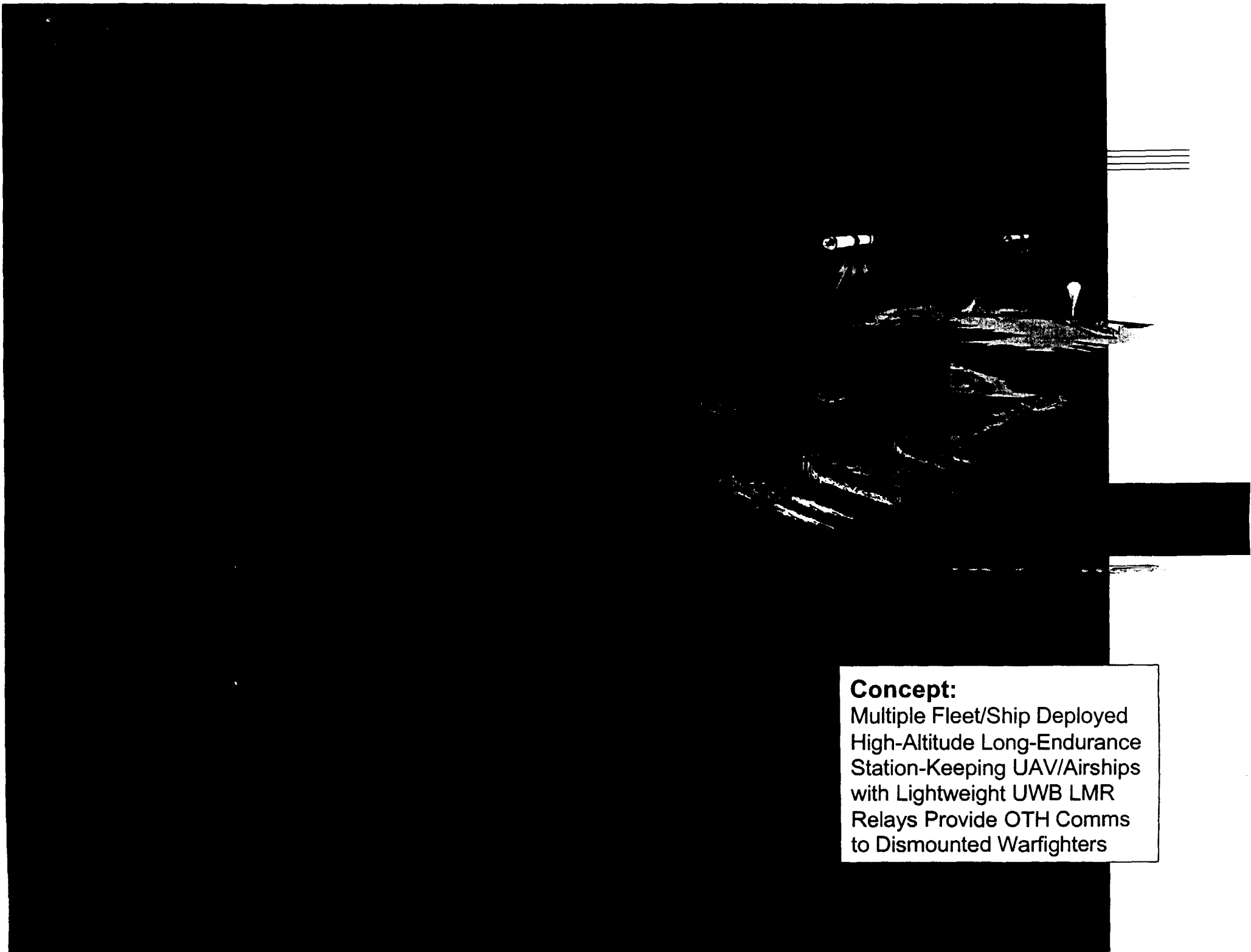
- **RQ-8 Vertical Takeoff UAV**

- 3 hrs 150 nmi, 12 hrs Total
- Payload Capacity = 300 lbs
- Comms Payloads
  - » (3) ARC-210 (Aircraft Radio)
  - » TCDL: 14-15 GHz, 10 Mbps
  - » SINCGARS to Ground MEUs



UCARS Ldg. Sys.





**Concept:**

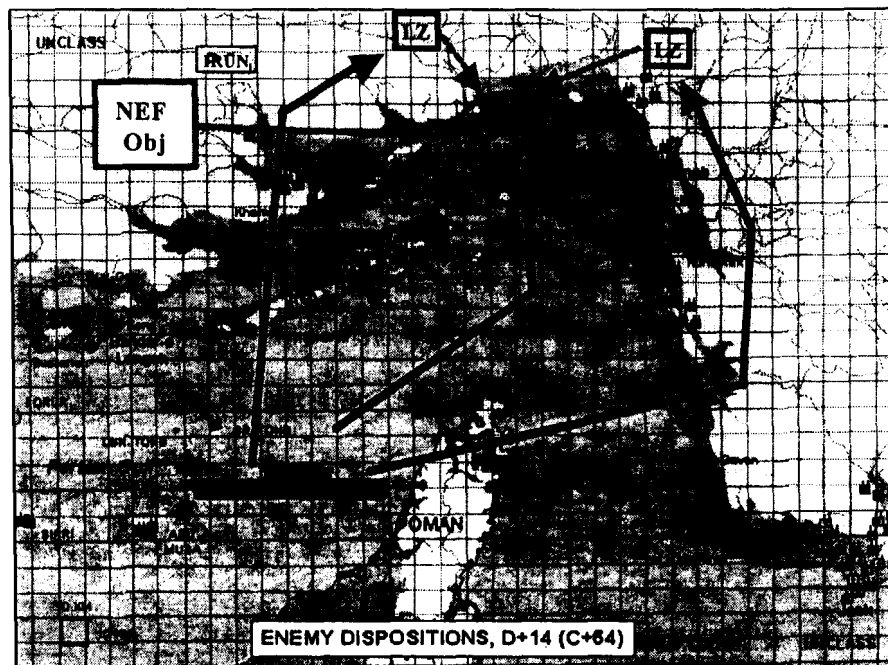
Multiple Fleet/Ship Deployed  
High-Altitude Long-Endurance  
Station-Keeping UAV/Airships  
with Lightweight UWB LMR  
Relays Provide OTH Comms  
to Dismounted Warfighters

# UWB Applications: Comms

DARPA

## Marine Corps OMFTS/STOM

- **High Capacity LOS Comms**
  - Replace MRC-142
    - » 576 Kb Ship-to-Shore, 25 nm
    - » Losing 1350-1850 MHz Band
- **Command Post on the Move**
  - Secure Wireless LAN
    - » Connect Servers Within CP
- **Convoys on the Move**
  - Inter-Vehicle Comms
- **Combat ID**
  - Geolocation
  - Surface Management
    - » Ship-to-Shore Movement: AAV & LCAC
- **Asset Visibility**





# UWB Applications: Comms

DARPA

## Urban Warfare

### • MOUT ACTD / USA / USMC

#### - Frustrated Requirements: C4I

- » R1: Identification of Friendly, Enemy, Noncombatants (IFF)
- » R3: Hands-Free Non-Line of Sight (NLOS) Communications
- » R7: Thru-Wall Sensing
- » R41: Position/Location Inside Buildings

#### - Military/Com'l Comms Inadequate

##### » Marine Corps Inter-Squad Radios (ISR)

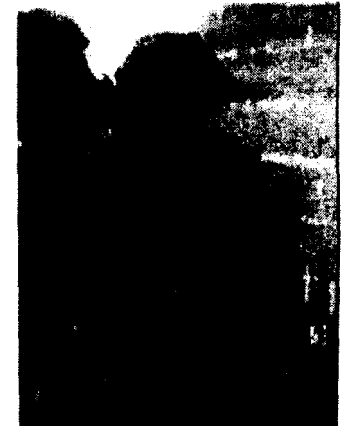
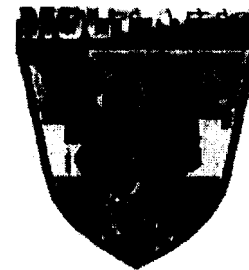
- ICOM UHF Radios: Non-Secure - 16,000 Units

##### » Need Secure Radio, 1-5 Km Range

- PRC-126 Size, Light Weight (Micro-UAV)
- C2 for Unmanned Ground Vehicles & Video

#### - Transition to Proposed Vanguard ATD '03

#### - Transition to SBCCOM Objective Force Warrior Program



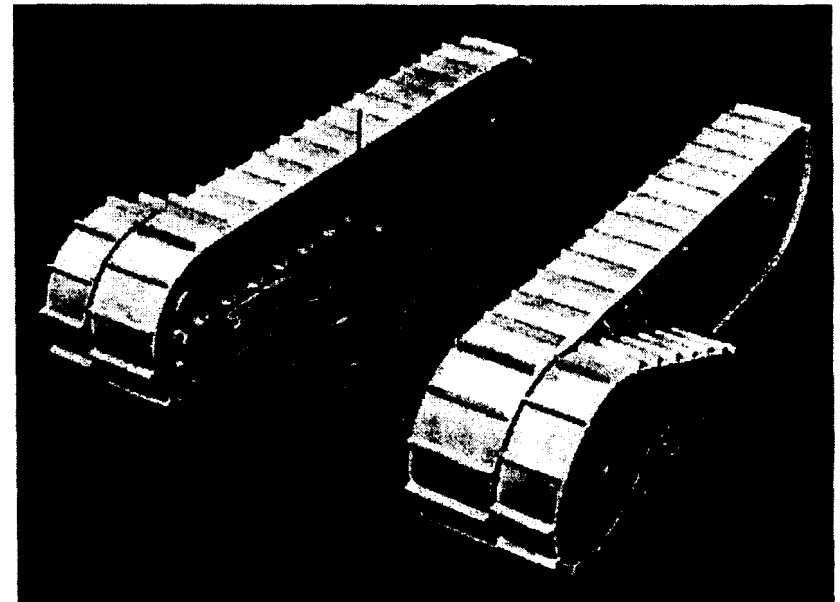
# UWB Applications: Comms



## Tactical Mobile Robots (TMR)

### • Imperatives

- Tele-Operation
  - » C2, Audio and Video
  - » Robots Talk to Each Other
- Geolocation / Navigation
  - » Robots Find Each Other
- Autonomously Reestablish Comms



### • Requirements

- |  |  |
|--|--|
| - Bandwidth <ul style="list-style-type: none"><li>» C2 &amp; Audio (low latency) 25 Kbps</li><li>» Video (B&amp;W, fuzzy, min) 100 Kbps</li><li>» Color Video (160x120) 1-2 Mbps</li><li>» High Res Video (320x240) 3 Mbps</li></ul> | - Weight & Power: 1-2 lb, 2-5 W  |
| - Range <ul style="list-style-type: none"><li>» 500m min (LAN Block Conv), 1-2 Km</li></ul>  | - Geolocation: 1 cm <ul style="list-style-type: none"><li>» Navigation/Mapping/Marsupial</li></ul>                                       |
|  | - Environment <ul style="list-style-type: none"><li>» Urban: Streets, Buildings, Sewers, Tunnels</li><li>» High EMI: DC Motors</li></ul> |

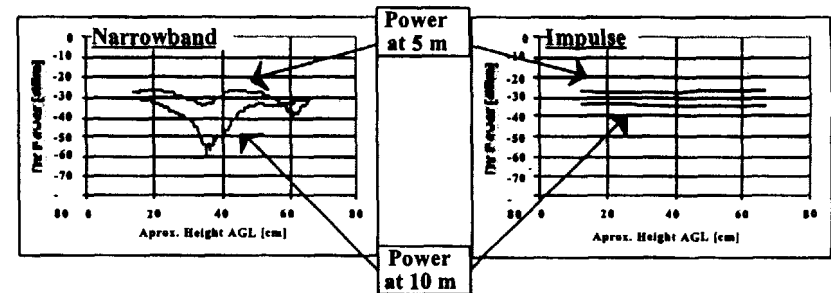
# UWB Requirements



## Advantages

### • Multi-Path

- Minimize Nulls in Urban Environments
- $1/r^2$  --  $1/r^4$  --  $1/r^6$  Losses
  - » 1 - 2 Orders Better than Narrow Band
    - Extra Transmitter Power Not Needed: 10-100X



### • Co-Interference

- FHSS: SINCGARS -- >2.5 Radios Co-located
- DSSS: Near-Far Power Management -- Qualcomm 1 dB Match Required
- UWB: 40-50 dB Rejection

### • Land Mobil Radio (LMR) / Cellular

- Greater Agility: No Critically Tuned Tanks / Combiners / Splitters
- No Dedicated Reservation Channel

### • Interceptibility

- Inherent LPI/LPD/LPE/AJ

### • Geolocation

- High Inherent Accuracy: Short Pulse Length  $\sim 1$  ns = 1 ft

### • Dual Capability: Communications and Geolocation Simultaneously

# UWB Requirements

DATA

## Architectures

- **Voice**
  - Inter Squad Radio (ISR)
  - Land Mobile Radio (LMR)
- **Data**
  - Burst Store & Forward
  - TCP-IP / Packet
  - Ad-Hoc Peer-to-Peer Networks
- **Video**
  - High Data Rate 1-3 Mbps
- **Geolocation**
  - Intra-Squad
  - Urban: Bldgs, Streets, Sewers
  - Alternate GPS

## Warfighter Requirements

- **Works Anywhere**
  - Urban
  - Triple Canopy
  - Mountain Terrain
  - No Terrestrial Infrastructure
- **Quality**
  - Fast Enough
  - Secure: LPI/LPD/LPE/AJ
  - 20 - 30 dB More Link Margin
- **Logistics**
  - Small
  - Light
  - Cheap

# Conclusion

DARPA

## Hunter Warrior AWE

- **Marine Corps Warfighting Lab**

- First AWE, 1997      All Data
- RMA: Asymmetrical Warfare

- **DARPA Provided Technology**

- Land Mobil Radio (LMR)
- Internet Node In the Sky (INITS)
- Shared Net: *Content Centric*
- ADOCS / LeatherNet (M&S)
- Surrogates, But They Worked

- **Burst Store & Forward**

- LMR: Serial, 2.7 Kbps
  - » Short Message: OTH Gold & VMF
  - » 3 Sec on Air, Hard to Locate
- INITS: TCP-IP, 300 Kbps Total



"In This World Where We're Carrying **Mobile Handsets**, I'm Afraid the Communications of the World's Most Advanced Military Are Operating at Levels that are 40 Years Out of Date."

Adm. Owens (ret)